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(54) Title: **METHOD FOR MANUFACTURING A PRODUCT HAVING LOCALLY SPECIFIC PROPERTIES**

(57) Abstract: A method for manufacturing a product having locally specific properties, the geometric form of which is described by a collection of polygonal basic figures, in particular in STL (structural triangulation language), comprises the following steps: selecting from the above basic figures a face part composed of coherent basic figures, adding to that face part at least one specific property, which during the manufacture of the product is to be given to the part thereof that comprises the above face part, optionally repeating the above process steps for other face parts to be selected, and manufacturing the product on the basis of the then obtained model information by means of a technique adding material in layers or in a die molding process, which includes giving the associated specific property during the building up in layers of at least the part of the product that comprises the above face part or during the injection molding.

Title: Method for manufacturing a product having locally specific properties

The present invention relates to a method for manufacturing a product having locally specific properties, the geometric form of which is described by a collection of polygonal basic figures, in particular in STL (structural triangulation language).

5        Such products can be manufactured by building up the product in layers by using all kinds of techniques adding material in layers, known under the designation LMT (layers manufacturing technology) or SFF (solid freedom fabrication), such as, for instance, stereolithography and selective laser sintering. It is also possible to manufacture such products in a die  
10       molding process, in which connection the term die is also understood to mean all types of punches and further tools that are necessary for manufacturing specific product forms. When designing and manufacturing such products, CAD/CAM systems are often used. It should be noted that a product built up in layers may also include a die which, in turn, can be used  
15       for manufacturing a further product having locally specific properties.

      In order to give in these known techniques the product to be manufactured a greater flexibility in appearance, material composition and/or physical or other properties, the method as described in the opening paragraph comprises according to the invention the following steps:  
20       selecting from the above basic figures a face part composed of coherent basic figures, adding to that face part at least one specific property, which during the manufacture of the product is to be given to the part thereof that comprises the above face part, optionally repeating the above process steps for other face parts to be selected, and manufacturing the product on the  
25       basis of the then obtained model information by means of a technique adding material in layers or in a die molding process, which includes giving

the associated specific property during the building up in layers of at least the part of the product that comprises the above face part or during the injection molding.

The above specific properties can relate to the color to be given to specific face parts, the material composition of specific parts of the product and/or the physical or other properties of specific parts of the product, such as the elasticity, the hardness and the like, or, when the method is used in a die molding process, the designation of the part of the product to be manufactured in a specific die half. When the product is a die, for instance a technique adding material in layers can be used for manufacturing parts of a die half from different materials. In this manner, different parts of the die can be given different properties, such as, for instance, a different heat conductivity, or the die can be locally provided with a wear-resistant layer in one operating cycle.

Moreover, several properties can be assigned to face parts, for instance both a specific material composition and a color. Adding specific properties to a face part means both directly assigning specific properties to the basic figures of the face part and indirectly assigning specific properties to the basic figures of the face part by assigning these properties to the face part, after which they are added to the basic figures which this face part is composed of.

The wall thickness of the face parts which together set up the model is zero, for which reason, after one or more specific properties have been given to one or more selected face parts, the model information then relating to a shell model (having wall thickness zero) will be converted into model information relating to a volumetric model, after which on the basis of the latter information the product is manufactured by means of a technique adding material in layers. Of course, this measure is not applicable in a die molding process. In fact, a CAD model, in which specific properties have

been added to the basic figures, remains a CAD model that can be directly supplied to a CAM system.

Selecting face parts can occur by displaying the geometric form of the product on the screen of a monitor belonging to a computer, indicating a polygonal basic figure on the monitor, after which all these basic figures are combined with the indicated basic figure to a face part, the normal vectors of which mutually or relative to the normal vector of the indicated basic figure do not exceed a preset angular difference.

Adding the face parts of specific properties can occur by selecting a code from the specific properties stored in code in the memory of a computer and adding them to file data belonging to the selected face parts. This code can be stored for each of the basic figures in the memory of the computer.

When the basic figures consist of triangles in STL, the code can be stored for each of the triangles in the memory space available in the STL file of each triangle. The standard available memory space is presently two bytes, so that for instance in the memory space available in the STL file of each triangle  $2^{15}$  color codes can be stored.

The invention further relates to a computer program used for manufacturing a product having locally specific properties, the geometric form of which is described by a collection of polygonal basic figures, in particular in STL (structural triangulation language), which program comprises the following steps: selecting from the above basic figures a face part composed of coherent basic figures and adding to that face part at least one specific property, which during the manufacture of the product is to be given to the part thereof that comprises the above face part, optionally repeating the above process steps for other face parts to be selected. The program can be used for manufacturing products both by means of a technique adding material in layers and in a die molding process. Specifically when using the former techniques, the program is of such design that, after one or more specific properties have been given to one or

more selected face parts, the model information then relating to a shell model is converted into model information relating to a volumetric model, after which on the basis of the latter information the product can be manufactured by means of a technique adding material in layers.

5        Finally, the invention relates to a computer system used during the manufacture of a product having locally specific properties, the geometric form of which is described by a collection of polygonal basic figures, in particular in STL (structural triangulation language), which computer system uses one of the above systems.

10        The invention will now be explained in more detail with reference to the accompanying drawing. In this drawing:

Fig. 1 shows a block-shaped model in STL having in relief thereon a letter T to be designed in another color than the block itself;

15        Fig. 2 shows a part of the letter T in Fig. 1, but in which the transition from the top face of the letter to the background is not sharp; and

Fig. 3 shows a cross-section of the part of the letter T shown in Fig. 2.

20        Although a geometric form can be described by a collection of polygonal basic figures in general, triangular basic figures will be started from hereinbelow, i.e. basic figures in standard STL (structural triangulation language), such as provided by a CAD system, for instance when using a "rapid prototyping technique". The STL file comprises a collection of triangles, each of which is described by three coordinates and a normal vector. Besides, per triangle two bytes are presently standard available for additional information. In the example described with reference to Fig. 1

25        this information will consist of a color code. Fig. 1 shows a block-shaped model in STL having in relief thereon a letter T to be designed in another color than the block itself. In order to be able to give each triangle a color code, the object, in this example the block-shaped model of Fig. 1, is displayed three-dimensionally on the screen of a monitor belonging to a

30        computer. Then a triangle, for instance triangle 1, is indicated on the screen

with the cursor. This is followed by automatically selecting all the always adjacent triangles that satisfy a preset criterion, that is to say that the angle between the normal vectors, also referred to as tolerance angle, of the always adjacent triangles must be smaller than a predetermined value. If in the example described here this tolerance angle is  $60^\circ$ , then, after indication of triangle 1, the triangles 2, 3 and 4 will be directly selected. By then selecting a desired color from a color code stored in the memory, the relevant code is added to the STL files of the triangles 1-4. Then background triangle 5 is to be indicated in this example, after which, by using the same criterion, the triangles 6-16 will be directly selected. Moreover, a color code can be added to the STL files of this group. After that this process can be repeated until a color code has further been added to the STL files of the triangles in all the vertical faces of the model shown in Fig. 1. In this manner, groups of triangles, that is to say face parts, are obtained, of which, for the relevant triangles, a color code is included in the STL files. Thus, for instance, the block in Fig. 1 can be given the color white, and the letter T provided thereon in relief can be given the color red. If in this example a tolerance angle of, for instance,  $100^\circ$  is selected as criterion for the vertical faces of the letter T and of the block, then, after a triangle has been indicated in a relevant vertical face, all the triangles in all the vertical faces of the letter T or of the block can be selected in one go. This, however, is only possible if the face parts already provided with a color code are excluded.

Problems can occur when the transition between two face parts is not sharp enough. This situation is shown in Figs. 2 and 3. Fig. 2 shows a part of the letter T in Fig. 1, but in which the transition from the top face of the letter to the background is not sharp, while Fig. 3 shows a cross-section of the part of the letter T shown in Fig. 2. In Fig. 2 the triangular structure is only shown in one of the transition faces from the upwardly projecting relief face to the background face. If the tolerance angle between two adjacent

triangles is always considered, then, after for instance indicating the upper triangle 17, all the triangles in the relevant transition face will be selected successively. It is also possible, however, to always compare the normal vectors of the relevant triangles with those of the triangle 17, so that, if an angle between the normal vectors of for instance  $30^\circ$  is taken as criterion, only the upper group of triangles is selected. This can be referred to as a relative tolerance angle in the first case and as an absolute tolerance angle in the second case.

Moreover, it is possible to display the cross-section on the screen (Fig. 3) and, by providing a window, to indicate the parts 18 of the relevant transition faces to which a specific color code is to be added.

By adding a color code in the STL files of the model, this is described in CTL (colored triangulation language). A CAD model in CTL can be supplied to a CAM system for designing a die, after which the products can be manufactured by means of a correspondingly realized die by injection molding, in which connection the color in which specific parts of the product are to be molded must be considered. In the example shown in Fig. 1, for instance, the block can be formed in one die half and the letter T in the other die half. By introducing a white plastic of for instance ABS (acrylonitrile-butadiene-styrene copolymer) into the die from one die half and, if this is sufficiently hardened, a red plastic of for instance PC (polycarbonate) from the other die half, a product sprayed in two colors can be obtained. The die, however, must then be designed in an appropriate manner.

In order to be able to manufacture a product in a technique adding material in layers, a model shown in CTL is insufficient. In fact, the wall thickness of the face parts which together set up the model is zero; such a model is further indicated as shell model. This shell model must be converted into a volumetric model.

After the face parts to be given a specific color have been selected, a conversion of the shell model built up by the common face parts into a volumetric model must take place. Successively shown in Figs. 4A-4C are a shell model of a cube-shaped object, a solid element model thereof and a solid element shell model of this object. Assuming the face parts formed by the four upright sides have been given the color codes blue (Bl), red (Re), green (Gr) and yellow (Ye), then the model 4A described in CTL must be converted into a volumetric model, that is to say in either the solid element model 4B or the solid element shell model 4C. In fact, a so-called "slice" can be made from these models 4B and 4C, that is to say a layer having an indicated thickness. The product can then be built up in a manner known for techniques adding material in layers by providing layers 19 on each other (Fig. 4C), while the different parts of each layer are provided in the indicated color.

The method in which a model in STL is converted into CTL, and if required subsequently into a volumetric model, is realized by means of a program appropriate therefor. The algorithm must then be such that the faces to be extruded do not intersect each other. In Fig. 5A three triangles are shown in CTL. If a solid element shell model is made therefrom without anything more, a product as shown in Fig. 5B will be obtained. Corrections in the algorithm must ensure that a model as shown in Fig. 5C is obtained. Of course, other corrections can also be made, if so desired.

The invention is not limited to the exemplary embodiments described herein with reference to the Figures, but comprises all kinds of modifications thereof, of course as far as falling within the scope of protection of the appended claims.

Thus, for instance, it is possible that the codes to be added to the model in STL not only relate to the color of selected face parts, but also to other specific properties or to combinations of specific properties, as already mentioned before. Thus, for instance, the upright red and yellow side faces



of the solid element shell model shown in Fig. 4C can be manufactured from a harder plastic than the blue and green upright side faces.

The method described herein is realized by means of computer programs specifically directed to selecting from the basic figures a face part  
5 composed of coherent basic figures and adding to that face part at least one specific property, which during the manufacture of the product is to be given to the part thereof that comprises the above face part, and optionally repeating these process steps for other face parts to be selected, or to  
converting the model information then relating to a shell model into model  
10 information relating to a volumetric model.

## CLAIMS

1. A method for manufacturing a product having locally specific properties, the geometric form of which is described by a collection of polygonal basic figures, in particular in STL (structural triangulation language), which method comprises the following steps: selecting from the  
5 above basic figures a face part composed of coherent basic figures, adding to that face part at least one specific property, which during the manufacture of the product is to be given to the part thereof that comprises the above face part, optionally repeating the above process steps for other face parts to be selected, and manufacturing the product on the basis of the then  
10 obtained model information by means of a technique adding material in layers or in a die molding process, which includes giving the associated specific property during the building up in layers of at least the part of the product that comprises the above face part or during the injection molding.
2. A method according to claim 1, characterized in that, after one or more  
15 specific properties have been given to one or more selected face parts, the model information then relating to a shell model is converted into model information relating to a volumetric model, after which on the basis of the latter information the product is manufactured by means of a technique adding material in layers.
- 20 3. A method according to claim 1 or 2, characterized in that selecting face parts occurs by displaying the geometric form of the product on the screen of a monitor belonging to a computer, indicating a polygonal basic figure on the monitor, after which all these basic figures are combined with the indicated basic figure to a face part, the normal vectors of which mutually or  
25 relative to the normal vector of the indicated basic figure do not exceed a preset angular difference.

4. A method according to any one of the preceding claims, characterized in that adding specific properties to the face parts occurs by selecting a code from the specific properties stored in code in the memory of a computer and adding them to file data belonging to the selected face parts.

5 5. A method according to claim 4, characterized in that the specific properties can be one or more of the following properties: the color of a face part, the physical properties of a face part, such as the material composition, and the indication of the part of a product that is to be manufactured in a specific die half.

10 6. A method according to claim 4 or 5, characterized in that the above code is stored for each of the basic figures in the memory of the computer.

7. A method according to any one of claims 4-6, in which the basic figures consist of triangles in STL, characterized in that the code is stored for each of the triangles in the memory space available in the STL file of each  
15 triangle.

8. A method according to claim 7, characterized in that  $2^{15}$  color codes can be stored in the memory space available in the STL file of each triangle.

9. A computer program for manufacturing a product having locally specific properties, the geometric form of which is described by a collection  
20 of polygonal basic figures, in particular in STL (structural triangulation language), which program comprises the following steps: selecting from the above basic figures a face part composed of coherent basic figures and adding to that face part at least one specific property, which during the manufacture of the product is to be given to the part thereof that comprises  
25 the above face part, optionally repeating the above process steps for other face parts to be selected.

10. A computer program according to claim 9, characterized in that in this program, after one or more specific properties have been given to one or more selected face parts, the model information then relating to a shell  
30 model is converted into model information relating to a volumetric model,

after which on the basis of the latter information the product can be manufactured by means of a technique adding material in layers.

11. A computer program used during the manufacture of a product having locally specific properties, the geometric form of which is described by a collection of polygonal basic figures, in particular in STL (structural triangulation language), which computer system uses a program according to claim 9 or 10.

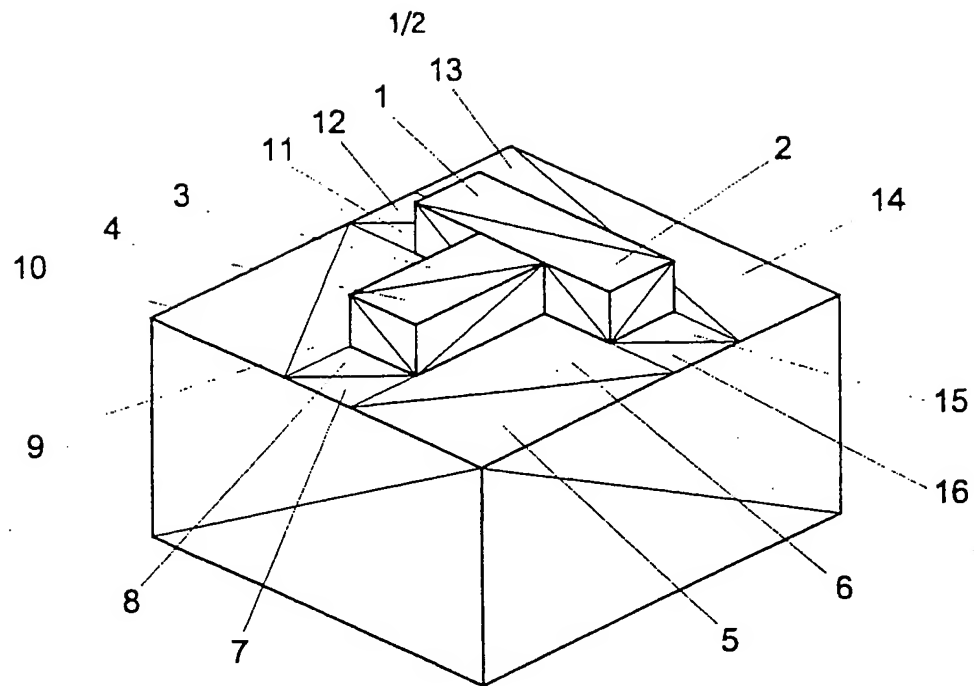


Fig. 1

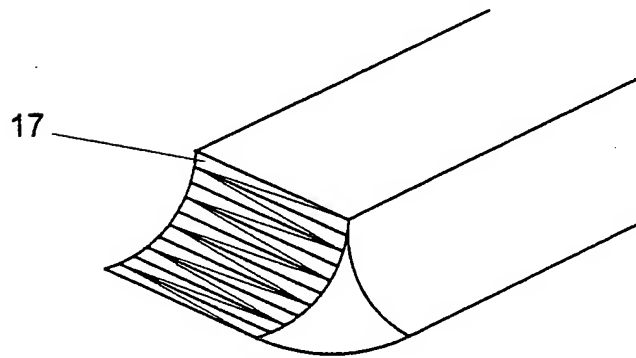


Fig. 2

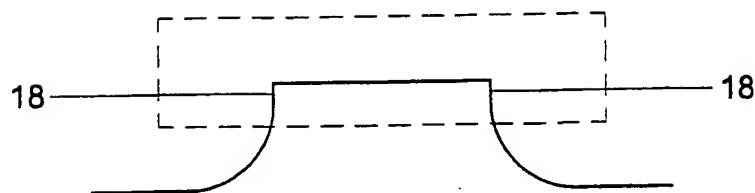


Fig. 3

2/2

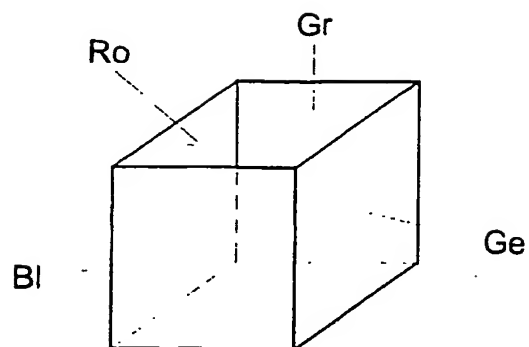


Fig. 4A

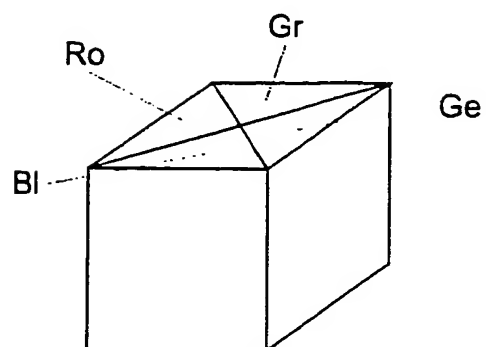


Fig. 4B

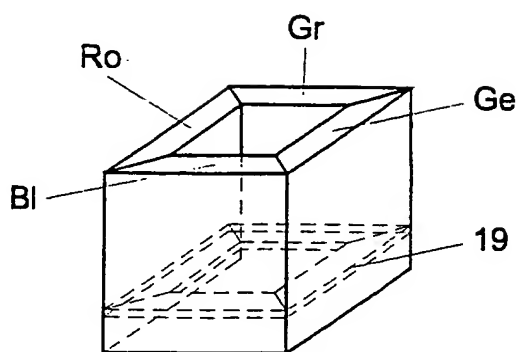


Fig. 4C

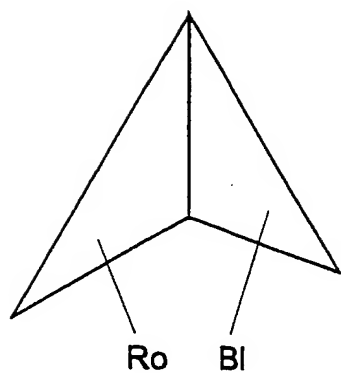


Fig. 5A

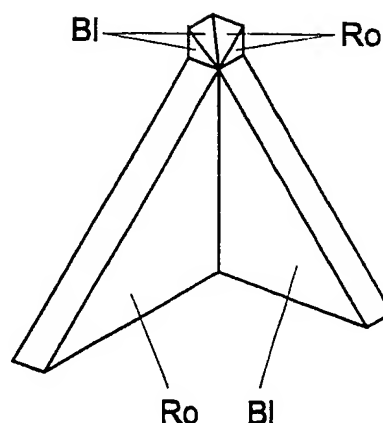


Fig. 5B

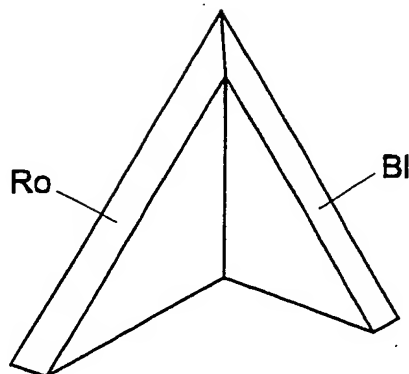


Fig. 5C

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(57) Abstract: A method for manufacturing a product having locally specific properties, the geometric form of which is described by a collection of polygonal basic figures, in particular in STL (structural triangulation language), comprises the following steps: selecting from the above basic figures a face part composed of coherent basic figures, adding to that face part at least one specific property, which during the manufacture of the product is to be given to the part thereof that comprises the above face part, optionally repeating the above process steps for other face parts to be selected, and manufacturing the product on the basis of the then obtained model information by means of a technique adding material in layers or in a die molding process, which includes giving the associated specific property during the building up in layers of at least the part of the product that comprises the above face part or during the injection molding.

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# INTERNATIONAL SEARCH REPORT

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, IBM-TDB

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 0 535 984 A (SPECTRA GROUP LTD INC) 7 April 1993 (1993-04-07) column 2, line 11 -column 3, line 50 ---	1-11
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Date of the actual completion of the international search

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